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ABSTRACT

This document reports on the 1974-75 Unified Science and Mathematics for Elementary Schools (USMES) evaluation investigating the cognitive and affective responses of USMES students to this interdisciplinary, process curriculum. It includes the results of a pre-post control group design to assess the curriculum's effects on students' basic skill development, their attitude change, and their progress in complex problem solving. The results of interviews with USMES teachers and students, unstructured observations at field sites, and the field staffs' documentation of USMES usage are also included. (Author/RC)

SUMMARY OF FINAL REPORT

Grant Number PES74-00542 A01

STUDENT EFFECTS OF AN INTERDISCIPLINARY CURRICULUM FOR REAL PROBLEM SOLVING: THE 1974-75 USMES EVALUATION

by

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REPORT SUMMARY

Focus for the 1974-75 Evaluation Project

This document reports on the 1974-75 USMES evaluation investigating the cognitive and affective responses of USMES students to this interdisciplinary, process curriculum. It includes the results of a pre-post control group design to assess the curriculum's effects on students' basic skill development, their attitude change, and their progress in complex problem solving. The results of interviews with USMES teachers and students, unstructured observations at field sites, and the field staffs' documentation of USMES usage are also included. A second report will document work on the development of new techniques for assessing student progress in complex problem solving.

The original proposal to the National Science Foundation for the continued evaluation of USMES during 1974-75 was broader in scope than the plan which was funded. As amended, the 1974-75 USMES Evaluation focused on student effects of the program: their abilities in problem solving; their basic skill development; their attitudes toward math, science, problem solving, and toward various learning activities embodied by the USMES philosophy. Teacher training, support networks for USMES users, formative program monitoring, material resource usage, and program dissemination patterns were deleted as areas for investigation. Clearly, the Foundation's overriding concern for an evaluation of USMES was the pursuit of an investigation of its "proof of concept," i.e. the examination of the students' problem solving abilities and basic skills as they develop under the influence of the USMES program.

Sample Selection, Data Collection, and Method of Analysis

Purposive sampling of new and experienced USMES teachers from 15 geographic areas was used to achieve a sample of USMES classes representing a cross section of grade levels, socio-economic levels, and unit challenges. Control classes came from non-USMES schools which were located in the same or neighboring communities as the USMES schools. These control classes were selected to match the USMES sample classes, one-for-one, on the bases of grade level, socioeconomic level, geographic area, and general features of the schools' program.

Responsible field staff personnel were trained to serve as on-site evaluators for the test administration and for the observation of class activities in these USMES and control sample classes. Interviews were completed by the evaluators with all 40 USMES teachers and 120 students in the evaluation sample. However, the maximum sample size achieved for other areas of the data collection was 37 USMES classes and 34 control classes.

The sample attrition from the proposed complement of 40 USMES and 40 control teachers can be attributed to problems with two observers who did not meet their commitments to data collection, and to the very stringent requirements of one state's law for permissions for pupil testing.

Several indicators in addition to the interview technique were used to acquire data on the program's effects on student performance. The pre-test, post-test control group design governed data collection on students' basic skill development, their performance in problem solving and changes in their attitudes toward math, science, problem solving and various learning activities. Six subtests from the Stanford Achievement Test battery were selected to measure basic skills. Problem solving ability was assessed with the Picnic

Problem and the Playground Problem--two tests of small group performance in simulated, real-life problem situations. A Likert-type attitude scale was developed to investigate attitude change.

The student performance data were submitted to two-factor repeated measures analyses of variance to determine if the treatment groups at each grade level had realized statistically significant gains from pre-test to post-test administration on any of the measures of performance. Whenever the data warranted and assumptions could be met, covariance analyses were also used to test the hypotheses that there were no significant differences between the treatment groups' adjusted post-test performances.

Characteristics of Experimental and Control Classes

One essential component of this evaluation is a description of what the USMES experimental program is like in practice, and how it differs from the treatment being applied to the comparative control groups. This documentation was necessary to make meaningful comparisons between the performance scores of students in the experimental program and the measures for students who did not receive the innovative curriculum.

USMES classes in the sample received diverse applications of the USMES program. Some USMES classes experienced brief applications of the program throughout the entire school year, while others had their USMES time concentrated in intensive periods over a few weeks only. Many combinations of levels of intensity and duration of usage were reported by the sample USMES teachers, but, on the average, classes spent 1½ hours a day, three days each week, for 12 weeks on an USMES unit. Most classes worked on only one unit during the year.

For most USMES classes, the time for USMES came primarily form science time. The statistically "average USMES class" reportedly borrowed some

additional time for USMES other subjects, most notably from social studies and language arts. Precise data on how teachers fit USMES into their overall programs could not be obtained without continual monitoring of USMES classes during the USMES and non-USMES portions of their curricula, before or after and during periods of USMES use.

The distribution of average time reportedly spent on non-USMES school subjects and activities for USMES classes when they did not pursue USMES was very similar to the distribution of average times reported for control classes. The measures of variability in these times for each subject or activity were very large in both the USMES group and the control group.

Similarly, both USMES and control groups represented tremendously variable patterns in the kinds of non-USMES curriculum materials and programs they used. There was as much variability within treatment groups as there was between treatment groups, except for the fact that no 1974-75 sample control classes were using or had used USMES.

Despite this variety in the nature and intensity of the treatments which the groups received, the results from the 1974-75 Class Activity Analysis indicated that there were clearly distinguishable differences observed in the kinds of activities pursued by USMES versus control students. Teachers continued to dominate class activity 16% to 20% of the time in both treatment groups. However, during the remaining observed class time, USMES students exhibited a wider repertoire of behaviors, and they spent larger amounts of time in more active, self-directed, and creative behavior than the control students. When the control students were not focusing on their teachers, they were spending much of the balance of the observed class time in very structured activities--prestructured reading, prestructured writing, and

calculating--probably on worksheets or in workbooks for mathematics and/or science.

Interview Results: Teachers, Students, Administrators

The interview was retained as a data collection strategy for the continued evaluation of USMES during 1974-75 because of the valuable insights gained from the previous year's interview results. A sample of 40 USMES teachers was selected to be interviewed by the two senior members of the evaluation team during the first three months of 1975.

For each USMES teacher interviewed three of his/her students were also interviewed. In addition, the evaluation staff members spoke informally with the administrators in the schools of both the USMES and control teachers.

The interviews focused on the effects of USMES or student and teacher behavior. Other issues arose in the course of the interviews with teachers and administrators, but these were discussed in a separate section of the report, since they do not relate directly to the questions in the interview schedules.

Most of the points in the chapter on the interview data came from pairs of sources: teachers and students; teachers and administrators. This built-in system of checks helped to establish the validity of the information. Another source of information, the observers at each site, served as an additional check-point.

There was no disagreement on the subject of children's enjoyment of USMES. The children did enjoy USMES and they looked forward to using it. All agreed that each child derived something from the program: increased knowledge in content areas, or ability to solve problems, or socialization skills, or

increased feeling of self-worth, or a confirmation of all three. What each child derived from USMES appeared to be a function of the teacher, the "challenge," and the child.

The philosophy of USMES received complete support from teachers and administrators. There was not a single instance of anyone in either group questioning the value of a problem-solving approach in education. Since these largely self-selected USMES users favored a real problem-solving approach, it follows that they also favored an integrated approach to teaching the disciplines, in order to solve the problems. And in theory, they did. In practice, there were difficulties. Departmentalized programs, rigid time schedules, and most teachers' limited content background (especially science) made the integrated approach difficult.

The nature of the USMES challenge was another factor which made the problem-solving approach and the integration of the disciplines difficult to implement. Some challenges simply did not lend themselves to a problem solving approach. Very often, the challenge was not perceived as a problem by the children, who simply saw what they did as a series of unrelated activities. In some instances, even the teacher did not perceive the USMES unit as a problem.

Administrators and teachers supported this perception by asking whether USMES was teaching problem solving or was just a series of activities, often seen as "gimmicks." For those students and teachers who saw a challenge as a problem, there was some feeling that the method of solution was generalizing to other areas.

While USMES appeared to be teaching new skills, it was seen mainly as reinforcing old learning. Teachers and students had no difficulty identifying

the specific aspects of mathematics being learned, but neither students nor teachers could identify very much science involved in the program. Other content areas, e.g., language arts, social science, were identified by some teachers as being heavily involved in the program.

Although the content emphasis was a function of the particular challenge, it was also a function of a specific teacher's likes and dislikes. Teachers still tended to stress those areas which interested them or which they felt most comfortable teaching. And so, they tended also to choose those challenges with which they felt most comfortable. As a result, those units which emphasized the social science contexts of mathematical applitations were most often used.

Teachers continued to learn to use the program through workshops or by word-of-mouth rather than by using the manual. Other materials developed specifically for USMES, e.g., how-to-cards and technical papers, were also getting minimal usage, both by students and teachers. Even the Design Lab usage declined noticeably from the previous year.

All-in-all, however, the interviews revealed that USMES appeared to be fulfilling some of its promises. There were indications that children felt capable of dealing with their environment, and that teachers, through less directive teaching, were encouraging children to solve their own problems. USMES seemed to be changing the behavior of both teachers and students, in what the developers could view as a positive way.

Basic Skill Development

Development of problem solving abilities and basic skill development are seen as two interdependent tasks for the USMES program. To fully evaluate the first, an examination of the second must also be made.

A pre-test, post-test control group design was used to investigate whether USMES students maintain the same level of basic skill development as control students, even though USMES usage may detract from the amount of basic skills instruction which USMES students can receive. Basic skill development was measured with Fall and Spring administrations of selected subtests of the Stanford Achievement Test Battery: (a) Reading Comprehension, (b) Mathematics Computation, (c) Mathematics Application, (d) Mathematics Concepts, (e) Science, and (f) Social Science.

Several problems were encountered in the collection, analysis and interpretation of the SAT data. However, none of these problems prevented an unequivocal response to the expressions of concern about accountability for the communication of basic skills. Clearly, USMES students do not fall behind their control counterparts in their performance on tests of basic skills. On all six post-test measures, the overall USMES mean was higher than the overall control mean, but the differences were not statistically significant.

The USMES program purports to enhance the problem solving ability of elementary school students without impairing their basic skill development. Indeed, the results of our analyses of basic skills data suggest that fears about impairment of basic skills of USMES students are unwarranted. The question which may merit further investigation is not whether USMES detracts from basic skill development, but whether USMES enhances basic skill development, especially for students in the higher grades of elementary school.

The largest increases in basic skill development were observed between the lower grade blocks. Of course, this pattern of development refelcts the growth curve found for many areas of intellectual and physical development. While not statistically significant, there was a noteworthy trend

for the growth rates of the control classes to fall behind those for the USMES classes at the upper grade levels.

Both USMES groups and control groups experienced similar rates of development in the basic skills in the early and middle elementary grades. Furthermore, both these control and USMES classes were generally close in average scores at pre-test time and at post-test time. However, the pattern changed for USMES and control groups in the higher elementary grades. While the USMES group exhibited continued growth in each of the six subtest areas, the control group revealed less growth or even showed a decline in performance.

This observation may be indicative of the effect of the USMES program on basic skill development at the higher elementary grade levels, but it may also be a function of sampling bias. Control classes were matched with USMES sample classes on the basis of grade level, socioeconomic composition and type of school program (traditional, "open," "non-graded," etc.), and the pairs of USMES and control classes came from neighboring schools. Nevertheless, careful matching on the most salient criteria is no assurance of comparability of treatment groups on all relevant factors other than the treatment.

Another point was raised in the discussion of basic skill development of USMES versus control students. It was a point of information which the evaluators uncovered during their interviews with USMES teachers. They found that USMES students have not been deprived of instruction in the basic skills. In some cases, they may have been getting more than the non-USMES students. Without exception, in all the USMES classes we interviewed, mathematics continues to be taught as a separate content area. These students were getting

their ordinary math instruction plus "USMES math." One might hypothesize, therefore, that USMES students should exceed the control group in mathematics performance.

As for science, in the majority of cases, USMES was the science program, for a portion of the school year, or for the entire school year, and one wonders if there would be any science if USMES was not presented. Therefore, in the math and science skills areas, USMES should not be interferring with basic skill development, but rather, adding to it.

In other skill areas, i.e. reading, language arts, and social science, our other sources of data support the conclusion that USMES is not taking much time from these areas. Some of the classes are not self-contained, and for these classes, schedules and amounts of time are mandated for basic skills instruction.

Clearly, USMES usage, as practiced by sample classes representing a wide distribution of geographic areas and socioeconomic levels, did not affect basic skill development adversely. Previous investigations on this issue yielded similar results. The measurement of basic skills has been a costly and time consuming activity and sample teachers, principals, and their students have become increasingly resentful that this kind of test administration is disruptive of the school day, and sometimes is threatening to students.

The evaluators recommend that the resources devoted to comparing the basic skill development of USMES and control students should not be expended in the future. Moreover, the issue of basic skill development should be of diminished importance in light of the patterns of USMES usage in most schools. Most frequently, the time for USMES comes from regularly scheduled science time, and to a lesser extent from project time. Hence, one should not expect

USMES children to fall behind in the basic skills areas of reading, language arts, and mathematics which are of primary concern to most elementary school personnel. Stated simply, the issue is not an issue.

Proof of Concept Assessment

An objective assessment of proof of concept of the USMES curriculum was limited by the primitive state of the art of measuring problem solving abilities in elementary school children. As the evaluation team pursued a two-fold thrust of program evaluation and new instrument development, we applied the most satisfactory existing measures of problem solving to answer immediate needs shared by the developers and the funding agency about the progress of USMES students in real, complex problem solving.

These measures were the Playground Problem and the Picnic Problem. The conceptual bases for these simulated, real-life-relevant problem tasks reflected John Dewey's conceptualization of the problem solving process, whose "five logically distinct steps" permeate much of the literature about USMES prepared by the USMES Central Staff.

Designed as parallel forms of one another, both problem tests are accompanied by manuals for trained administrators' presentation of the tests to groups of five children.

The scoring protocols developed for the tests offer both cognitive and affective assessments. The cognitive scores provide indices of the students' abilities to identify, measure, calculate, and record data on factors which they think are salient to the solution of the problems. The behavioral assessments include ratings on motivation to accept the problem, commitment to task, efficiency of manpower, and the nature of group leadership. Additionally, the protocol for the Playground Problem afforded an assessment of the students'

product: their drawing of the play area design.

Neither the Playground Problem nor the Picnic Problem satisfied the program developers' concerns that these tests meet all of their criteria for "realness." Therefore, rigorous investigation of these tests' reliability and statistical validity did not seem to be warranted. Content validation of the tests as simulated measures of life-like, complex problem solving was established.

No differences between USMES and control students were noted in the behavioral aspects of their work on the problems. The four cognitive scores were subjected to repeated measures analyses of variance and to analyses of covariance. Consistently, significant differences among grade levels were observed for all four cognitive aspects of the students performance. As one might expect, the older students in both treatment groups outperformed the younger students. They identified more factors and progressed to more frequent, higher level measuring, calculating, and recording on these factors. However, no significant differences between treatment groups were found on any of the ratings derived from the scoring protocol.

Attitude Changes in USMES and Control Students

Having analyzed the cognitive effects of the USMES program, on its students, the evaluation team then truned its focus on the affective dimension. What is the impact of USMES on the students' attitudes?

An attitude scale was developed and pilot tested by the evaluation team especially for this USMES evaluation. The scale consisted of two parts. Part I contained items designed to measure attitudes toward math and science and toward various teaching strategies and learning activities which are embodied in the USMES approach. Part II began with a statement of a real-life,

complex problem facing a group of engineers, and then followed with a series of items.

Factor analyses of the largest data base, the post-test attitude results for 1491 students, yielded 7 factors on Part I and 4 factors on Part II. The repeated measures analyses revealed highly significant ($p < .0001$) pre-to-post test administration differences for most of the 11 factors. Only the academic insecurity scale from Part II produced no significant pre- post-test differences.

However, these pre-to-post differences may be indicative only of "time-of-year" effects, as discussed by Ahlgren. This evaluation did employ a control group design but fall-fall testings were not feasible because samples would not have been accessible the second fall. There were no treatment by test administration interactions resulting from our analyses. Both treatment groups moved in the same direction. But in light of Ahlgren's and his associates' observations, our results are very interesting because on most of the scales, the groups attitudes moved toward the more socially or academically desirable direction, up or down, over the course of the school year.

The time-of-year effect observed by Ahlgren et al. is probably evidenced in the overall decline of students' scores on factor 4, Group Learning, and on factor 6, Self-Directed Learning, over the period from Fall to Spring. At the end of the school year, students, perhaps, are tired or less motivated, and would prefer to play a more passive role in learning, as the teacher "runs the show."

While there were no significant treatment differences revealed by repeated measures analyses, there were a number of significant grade differences in attitude factors which have implications for USMES development and USMES usage,

even though the grade differences did not interact with treatment when covariance adjustments were made. Guidelines for curriculum development and implementation which come from research in developmental psychology are reinforced by some of the grade differences observed in this affective evaluation.

Students in the upper grades expressed a greater preference for self-directed learning activities, were less concerned with pleasing the teacher and consenting to the answer held by the class, and were less inclined to believe that only one solution is best for a complex problem.

The students we tested, both USMES and control, were very positive in their attitudes toward arithmetic. They enjoyed it very much, and this enjoyment increased over the school year and perhaps further over grade levels. Statements about increased enjoyment in higher grades must be tenuous because the research was cross sectional and not longitudinal.

The factor structure emerging from the factor analysis of our scale suggested that students could distinguish between the attributes of enjoyment and value with respect to arithmetic. Not only did the students in our sample enjoy arithmetic very much, they also valued it highly, and their average ascription of value to arithmetic was hightened almost to limit of our measurement scale on the post-test.

These expressions of positive regard for arithmetic were corroborated, in part, by the results of our interviews with 120 USMES children. When asked what they had done in school that year that they particularly enjoyed, approximately half of the student interviewers responded "math!" or "arithmetic!" without prompting.

The descriptive statistics summarizing the treatment groups' pre- and post-test positions, at each grade level, on the scale of science appreciation were also noteworthy. For all categories, initially positive expressions of science appreciation became more positive over the course of the school year. This result may be indicative of a slowing-down or a reversal in the trend of older students' generally negative attitudes toward science and scientists which was observed in the 1950's (Heath, Maier, Remmers, & Rogers, 1957). Almost two decades of intensive science curriculum development activity have followed. Many studies of the cognitive outcomes of new methods of science instruction have appeared since 1957. However, it is difficult to obtain a picture of the effects of these curricula on the development of affective behaviors of students; the cognitive studies proliferate, but the research on affective responses to science curricula is disproportionately smaller (Kahn & Weiss, 1973, p. 784).

Only one treatment difference closely approached statistical significance, but that difference may have special practical significance: USMES students tended to express greater appreciation for science than did control students.

Recommendation for a Future Study

Considerable information was volunteered to the senior evaluators by teachers and administrators at almost all of the USMES sites on a singular theme. In effect, the "feedback" indicated a serious morale problem growing among the implementation and developmental teachers and their sponsoring principals, threatening a possible movement to disengage from the program. The evaluators were not charged with the investigation of this issue, nor did they have the necessary instruments to document of "objectivize" its content. However, because of the serious possible implications of this issue for the future

dissemination of the USMES program, a recommendation for its future investigation and rectification was advanced.

Conclusion

In sum, this evaluation documents the decided perceptions of the USMES teachers that the USMES program does teach problem solving skills to its students, while the more objective instruments to measure problem solving skills are still too unsophisticated to give an accurate reading of this same question. Basic skills of USMES students, according to both teacher perceptions and objective tests, have not suffered. Additionally, results from the interviews with teachers and students documented the "excitement" for learning self-initiation and social interaction skills acquired by students in USMES classes. In their work on real problems, USMES students sensed that their efforts can make a difference.